Bioactive compounds of seeds from raspberry (*Rubus idaeus* L.) cultivars grown under the Norwegian conditions

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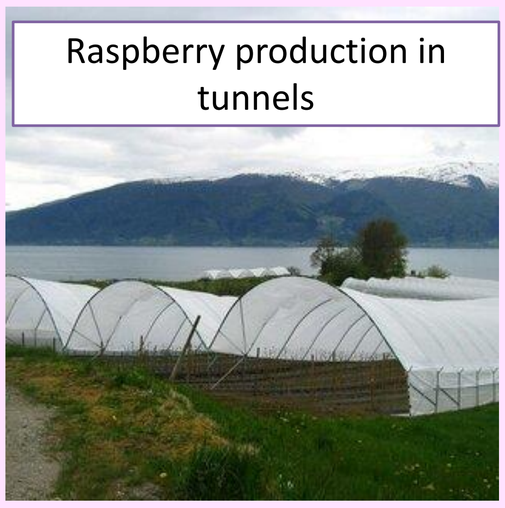
1. INTRODUCTION - *Rubus idaeus* production is an important high-value horticultural industry in Europe (mostly in northern and central European countries) because it provides incomes directly from agriculture and indirectly from food processing and confectionery. Raspberries are considered enjoyable, refreshing fruits with an outstanding taste and aroma that provide energy and contribute to a balanced diet (Fotirić Akšić et al., 2022). They are consumed as table fruit, but very often, they are sold as frozen, canned, or dried and are used for making raspberry puree and juice concentrate. They are considered to be a plant from nature's treasure chests due to their high levels of many nutrients, including essential minerals (Mg, K, Cu and Fe), sugars, organic acids, vitamins, carotenoids, phenols, fatty acids, stilbenes (resveratrol), tannins, lignans, and dietary fibers (Pantelidis et al., 2007; Krstić et al., 2019). The most abundant fatty acids of raspberry seed oil are linoleic, α-linolenic, and oleic acids, which together comprised 96% of the total fatty acid (Oomaha et al., 2000). Besides, it is rich in polyphenol compounds, phytosterols, carotenoids, tocopherols and tocotrienols (Šućurović et al., 2009). The microconstituents of raspberry seed oil with its rich array of phytochemicals, suggest that it has nutraceutical properties. According to numerous patents, raspberry seed oil can be used in technology processes, pharmaceutical, cosmetic, bathing products, oral care and as a food (Ispiryan et al., 2021). In Norway, raspberries are produced on 400 ha, with total yields of ~2060 t (FAOStat, 2022). Raspberry production is organized both in open fields and in tunnels along the west coast fjords up to 65° N, where the climate has proved to be very suitable for this kind of production. The cultivar 'Veten' (intended for jam production) was the main cultivar for more than 30 years, but nowadays, the Scottish cultivar 'Glen Ample' (intended for fresh consumption) dominates the raspberry industry. The objective of this study was to analyse fatty acids and polyphenolic composition of seeds from 17 raspberry (*Rubus idaeus* L.) cultivars grown in Norway.



2. MATERIALS AND METHODS - The composition of fatty acids was determined according to the standard method by capillary gas chromatography. The separation and quantification of the polyphenols were performed using a Dionex Ultimate 3000 UHPLC system connected to TSQ Quantum Access Max triple-quadrupole mass spectrometer equipped with heated electrospray ionization (HESI) source.

3. RESULTS AND DISCUSSION - Out of 25 detected fatty acids, unsaturated linoleic acid (up to 58.65% in `Borgund`), linolenic acid (up to 37.31% in 'Stiora') and oleic acid (up to 17.72% in `Agat`) were the most abounded (Tabl. 2). Saturated fatty acids palmitic and stearic acids were quantified in small amounts and the highest were in `Balder` (up to 2.38% and 0.80%, respectively). The sum of quantified polyphenols were the lowest in the cultivar `Ninni` (953.0 mg/kg) and the highest in `Glen Dee` (1829.69 mg/kg). Ellagic acid was predominant in raspberries seeds, and it ranged from 884.72 (`Stiora`) to 1611.76 mg/kg (`Glen Dee`), followed by *p*-coumaric acid (from 2.18 in `Vene` up to 118.69 mg/kg in `Glen Dee`) and quercetin 3-*O*-glucoside (from 2.73 `Anitra` up to 24.92 mg/kg `Glen Ample`) (Tab. 1).

Table 1. The averages values of contents of the most aboundant polyphenols (mg/kg) in raspberry seed oil

Cultivar/polyphenolic compound	5-O-Caffeoyl. acid	Caffeic acid	Rutin	p-Coumaric acid	Quercetin 3-O-glucoside	Catechin gallate	Ellagic acid	Isorham. 3-O-rutinoside	Kaempf. 3-O-glucoside
Ru04003090	4.76d*	2.85bc	5.08b	112.58k	6.43ab	9.94d	1129.84c	7.25a	3.01c
MALLING JUNO	5.85e	5.55d	8.80d	34.60g	6.83ab	15.78f	1448.59f	7.46a	2.80c
GLEN AMPLE	6.74f	3.86c	6.49c	69.75j	24.92g	7.66c	1331.61e	12.33cd	5.36d
GLEN FINE	5.46e	5.69d	6.11bc	47.07h	6.85ab	9.50d	1513.86g	11.22c	7.25e
CASCADE DELIGHT	3.38c	3.76c	7.71cd	53.72i	17.68f	19.27g	1603.76g	9.36b	5.00d
GLEN DEE	4.95de	18.79e	4.77b	118.69l	24.04g	12.01e	1611.76	13.11d	5.19d
AGAT	3.38c	2.36b	4.06b	20.76e	8.92b	7.65c	1263.78d	6.55a	1.65b
ANITRA	3.06c	2.45b	2.33a	22.74e	2.73a	7.94c	1359.26e	6.46a	1.39b
ASKER	3.54c	2.80bc	3.67ab	11.12c	5.96ab	5.41b	983.47b	7.02a	1.95bc
BALDER	3.65c	3.71c	2.48a	21.63e	12.37d	9.41d	1351.67e	15.40e	3.07c
BORGUND	3.29c	2.35b	6.04bc	26.94f	11.55cd	12.19e	1462.54	12.36c	2.03c
NINNI	3.16c	2.52b	7.27c	6.56b	6.50ab	12.77e	892.04a	7.14a	1.52b
PREUSSEN	1.70 a	4.99d	6.20bc	15.40d	9.76bc	13.38e	1117.78c	8.22ab	2.58c
STIORA	2.43b	2.40b	4.51b	26.18f	10.37c	8.37c	884.72a	6.71a	2.46c
VARNES	2.44b	3.64c	3.03a	11.25c	14.43e	7.40c	991.24b	5.85a	2.84c
VENE	1.24a	0.89a	2.29a	2.18a	4.96b	2.61a	1198.00c	6.47a	0.51a
VETEN	2.50b	3.65c	6.00bc	26.58f	10.93c	8.09c	1220.04d	7.06a	2.42c

* Different letters in the same column denote a significant difference according to LSD test ($p < 0.05$).

Table 2. The averages values of contents of the most aboundant fatty acids (%) in raspberry seed oil

Cultivar/Fatty acid	Palmitic acid (C16:0)	Heptadecanoic acid (C17:0)	Stearic acid (C18:0)	Oleic acid (C18:1) and its isomers	Linoleic acid (C18:2) and its isomers	Linolenic acid (C18:3)	Arachidic acid (C20:0)
Ru04003090	1.93ab	0.28d	0.51bc	10.61b	54.58b	31.62d	0.17bc
MALLING JUNO	1.86a	0.37e	0.60c	11.05c	55.89bc	29.82c	0.16b
GLEN AMPLE	2.08c	0.69g	0.57c	11.94cd	55.33bc	28.87c	0.16b
GLEN FINE	2.05bc	0.25d	0.50bc	11.22c	53.44b	32.11de	0.16b
CASCADE DELIGHT	1.87a	0.36e	0.39a	13.10e	57.93cd	25.87b	0.14a
GLEN DEE	2.07c	0.36e	0.61c	9.45a	53.46b	33.68e	0.14a
AGAT	2.38f	0.58f	0.80e	12.73de	56.96c	24.55ab	0.24e
ANITRA	2.37f	<0.02a	0.58c	11.15c	53.66b	31.24d	0.20d
ASKER	2.18de	0.05b	0.60c	11.53c	54.68b	30.06cd	0.21d
BALDER	2.25e	<0.02a	0.71d	17.72h	56.25c	22.03a	0.20d
BORGUND	1.98b	<0.02a	0.55c	11.23c	55.60bc	29.82c	0.23e
NINNI	2.17d	0.02b	0.49bc	12.22d	57.90cd	26.38b	0.21d
PREUSSEN	2.04bc	0.25d	0.47b	14.47f	49.89a	31.96d	0.19cd
STIORA	2.20e	0.16c	0.47b	13.21e	58.65d	24.34ab	0.23e
VARNES	2.09c	<0.02a	0.54c	15.75g	56.83c	23.77a	0.23e
VENE	2.19de	<0.02a	0.35a	10.30b	48.99a	37.31f	0.14a
VETEN	2.14d	0.35e	0.48b	9.61a	56.55c	30.31cd	0.18c

* Different letters in the same column denote a significant difference according to LSD test ($p < 0.05$).

4. CONCLUSION - The variation in analyzed content of the studied chemical compounds in Norwegian raspberry seeds helped us differentiate examined cultivars and proved that the kernel`s composition was attributed to genetic factors. Besides, according to polyphenolic and fatty acids profile, can be concluded that raspberry seeds can be used for the production of `functional food`.

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